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FREE-SPINNING-TUNNEL TESTS OF A MODEL OF

A CANARD AIRPLANE

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NACA

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SUMMARY

A series of tests was made in the NACA 15-foot free-spinning tunnel to study the spin characteristics of a 1/24-scale model of a hypothetical canard airplane, which was designed to be the same size and to have the same general aerodynamic characteristics as a Boeing B-247 airplane. The model had a single fin and rudder at the rear of the fuselage.

The model spun normally and had excellent recovery characteristics. Moderate variations in mass distribution, center-of-gravity location, or changes in horizontal or vertical control surfaces had only moderate effects upon the recovery characteristics of the model. A few spins were very oscillatory.

INTRODUCTION

The wing loading and the power of present-day airplanes are constantly increasing. As a result, the slipstream produces uncertainty in and generally has adverse effects on the stability and the control characteristics. With a view toward overcoming these difficulties, some designers are reconsidering the possibilities of the canard airplane. Because data on the spinning characteristics of this type of airplane are lacking, tests were conducted in the NACA 15-foot free-spinning tunnel to determine the spin and recovery characteristics of a canard airplane, originally designed for tests in the NACA gust tunnel (reference 1), of the same size and with the same general aerodynamic characteristics as a Boeing B-247 airplane.

The model was tested not only at an estimated normal loading condition but also with the center of gravity moved

forward and rearward, with the loading increased and de-
creased along the fuselage and along the wings, and with
the areas of the horizontal and vertical control surfaces
increased and decreased. Inverted spins were tested for
only the normal loading condition.

SYMBOLS

z/c ratio of distance between center of gravity and
       center line of fuselage to mean geometric chord

x/c ratio of distance of center of gravity from leading
       edge of mean geometric chord to mean geometric
       chord

I_X, I_Y, and I_Z moments of inertia about body axes X,
       Y, and Z, respectively

b wing span

α acute angle between thrust axis and vertical, degrees
       (approx. equal to absolute value of angle
       of attack at plane of symmetry)

ϕ angle between span axis and horizontal, degrees
       (whether inner wing tip is up or down is indi-
       cated on charts as U or D, respectively)

V full-scale true rate of descent, feet per second

Ω resultant angular velocity, radians per second

R/b radius of spin of airplane center of gravity divided
       by span

β angle of sideslip, degrees (positive is inward in
       spins to pilot's right)

APPARATUS AND MODEL

The tests were made in the NACA 15-foot free-spinning
tunnel in the manner described in reference 2.

The model used in the present tests was a 1/24-scale model of a hypothetical canard airplane having the general characteristics given in the following table:

Weight, lb 14,600
Wing span, ft 74
Over-all length, ft 66
Gross wing area, sq ft 836
Wing loading, lb/sq ft 17.5
Wing section . . . . NACA 0015
Wing mean geometric chord, ft 11.3
Ratio of vertical tail length (distance from
    c.g. to rudder hinge axis) to wing span 0.425
Ratio of horizontal tail length (distance from
    c.g. to elevator hinge axis) to wing span 0.249
Stabilizer area, sq ft 135.9
Total area of elevators, sq ft 47.5
Fin area, sq ft 28.8
Rudder area, sq ft 30.7

The model, which had been previously used for the gust-tunnel tests reported in reference 1, was constructed principally of balsa wood. The fuselage was hollow and the wings were of spar and rib construction covered with tissue paper. Because this model was representative of the canard type of airplane and did not represent any particular airplane, engine nacelles and other protuberances were not installed. Lead weights were suitably disposed to give the proper total weight and mass distribution. For the spinning tests, the model was modified by the addition of movable control surfaces and by the installation of a remote-control mechanism to move the rudder for recovery tests.

Photographs of the model are shown in figure 1. Figure 2 gives a three-view drawing. The original and the modified tail surfaces are shown in figure 3.

TEST CONDITIONS

The model was ballasted to represent the normal loading of the hypothetical airplane at an equivalent spin altitude of 7200 feet and corresponded to the following

full—scale mass distribution with landing gear retracted:

Weight, lb 14,600
x/c . . . . 0.35 ahead of L.E. of M.G.C.
z/c . . . . 0.024 below center line of fuselage
I_X, slug—ft^2 33,500
I_Y, slug—ft^2 58,200
I_Z, slug—ft^2 87,500

The following typical maximum control deflections
were used for these tests:

Rudder . . . . $\pm 30^\circ$
Elevators . . . . 25° up and 35° down
Ailerons . . . . 30° up and 20° down

RESULTS

The results of the tests are presented in charts 1
and 2. The steady—spin parameters presented in the charts
were determined by the methods described in reference 2
and have been converted to corresponding full—scale values.
The data presented are for erect and inverted spins to the
pilot's right. Control positions indicated in the charts
are for the steady spin prior to recovery attempts. Re-
covery was attempted, in every case, by reversing the
rudder rapidly from full with to full against the spin.

Recovery is measured by the number of turns the spin-
ning model makes from the time the rudder is moved until
the spin rotation ceases.

DISCUSSION

Normal loading.— The effect of various control posi-
tions upon the spin and recovery characteristics of the
model with normal loading is shown in chart 1. Quantita-
tive results were not obtained for the spin with ailerons
neutral and stick back (elevators down) because the model
wandered about excessively. Data were obtained for ailer-
ons with the spin (right aileron up in a right spin) and
also for ailerons against the spin. These spins were quite
oscillatory and recoveries were rapid although the spins
were not steep.

When the stick was forward (elevators up), the spins were steeper but recoveries were slightly slower than for stick neutral or back.

Placing the ailerons full with the spin resulted in fairly flat oscillatory spins when the stick was neutral or back and in a steep spin when the stick was forward.

Regardless of elevator or aileron position, the spins obtained were oscillatory and recoveries were rapid. The effectiveness of the rudder over the range of attitudes covered is probably a result of the fact that the rudder was not shielded by the tail plane as might occur for a conventional design. In general, the recoveries made by rudder reversal when the stick was back resulted in stalled glides; whereas recoveries made by rudder reversal when the stick was forward resulted in dives.

Alternate loadings.- Moderate fore-and-aft variations in the center-of-gravity location of the model amounting to 5 percent of the mean geometric chord had but small effect upon the spin and recovery characteristics of the model. When the center of gravity was moved forward, the spins were slightly steeper and less oscillatory than for the normal center-of-gravity location.

Extending or retracting mass along the fuselage (changing I_Y and I_Z by 15 percent of I_Y) or extending or retracting mass along the wings (changing I_X and I_Z by 26 percent of I_X) had but small effect on the spin and recovery characteristics.

Over the range of loading conditions tested, spins obtained with the stick forward showed higher values of angular velocity Ω and of $\Omega b/2V$ than spins with stick back.

Effects of changes in areas of tail surfaces.- In order to determine whether the spin characteristics were critically dependent on the size of the tail surfaces, tests were made with the vertical-tail height constant and with (1) fin area increased and decreased 40 percent, (2) rudder area increased and decreased 40 percent, and (3) fin and rudder area simultaneously increased and decreased 40 percent. A similar series of changes was made in the horizontal surfaces with the span constant. (See fig. 3.)

The effects of these changes were not very marked. There was some tendency for increased rudder area to give slightly flatter spins but faster recoveries and for decreased rudder area to have the opposite effect. Decreasing the size of the horizontal tail plane tended to make the spins steeper and the recoveries slower; increasing the size of the horizontal tail plane had the opposite effect.

Inverted spins.— The model would not spin inverted unless the ailerons were with the spin (stick and rudder controls crossed in the steady spin) or unless the ailerons were neutral and the stick forward. Recovery by rudder reversal was rapid from all spins obtained. The results are presented in chart 2.

CONCLUDING REMARKS

From the tests of a 1/24-scale model of a hypothetical canard airplane, which had a single fin and rudder at the rear of the fuselage and a tail length measured from the center of gravity to the hinge line that was comparable to that of conventional airplanes, the following conclusions have been drawn:

1. The spin characteristics were generally similar to those for conventional airplanes.

2. Although spins for some test conditions were fairly flat, recovery by rudder reversal was rapid in every case. The effectiveness of the rudder was apparently due to the fact that, for this design, the rudder is not shielded by the tail plane.

3. Moderate changes in mass distribution and tail size did not seriously alter the spin characteristics.

4. The model spun inverted for only a few control positions.

It should be realized that there have been other projected arrangements for canard airplanes, some having four engines with a large increase in weight along the wings and some having vertical tail surfaces mounted on

the wing tips. The spin characteristics of these types would be expected to differ from the characteristics of the design studied in the present investigation.

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    National Advisory Committee for Aeronautics,
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REFERENCES

1. Donely, Philip, Pierce, Harold B., and Pepoon, Philip W.: Measurements and Analysis of the Motion of a Canard Airplane Model in Gusts. T.N. No. 758, NACA, 1940.

2. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. Rep. No. 557, NACA, 1936.

CHART 1

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EFFECT OF CONTROLS ON SPIN AND RECOVERY CHARACTERISTICS OF $\frac{1}{24}$-SCALE MODEL OF CANARD AIRPLANE - ERECT SPINS TO PILOT'S RIGHT

[Normal loading; recovery by rapid full rudder reversal; recovery attempted from,
and steady-spin data presented for, rudder-with spins]

Too wandering and
too large radius
of spin to test

37 to 67	9U to 28D	
122	.29	.36	-1
$\frac{1}{4}$		

35 to 49	0 to 12D	
145	.24	.58	-11
$\frac{1}{4}$		

ELEVATOR DOWN   STICK BACK

Too oscillatory in
pitch to test
completely.

38 to 57	3D to 25D	
127	.28	.39	+2
$\frac{1}{4}$	$\frac{1}{2}$	

AILERONS WITH

| 167 | .33 | | |

AILERONS AGAINST

36 to 50	1U to 15U	
122	.34	.42	-20
$\frac{1}{4}$		

ELEVATORS UP   STICK FORWARD

29 to 39	0 to 9D	
172	.41	.19	-5
$\frac{3}{4}$		

34 to 45	0 to 1D	
154	.39	.19	-8
1, 1		

32 to 40	0 to 8U	
149	.38	.24	-13
$\frac{3}{4}$	$\frac{3}{4}$	

Range of values
during spin

α		ϕ	
V	$\frac{\Omega b}{2V}$	$\frac{R}{b}$	β
Turns	for	Recovery	

Chart 1

CHART 2

EFFECT OF CONTROLS ON SPIN AND RECOVERY CHARACTERISTICS OF $\frac{1}{24}$-SCALE MODEL OF CANARD AIRPLANE - INVERTED SPINS TO PILOT'S RIGHT

[Normal loading; recovery by rapid full rudder reversal; recovery attempted from, and steady-spin data presented for, rudder-with spins]
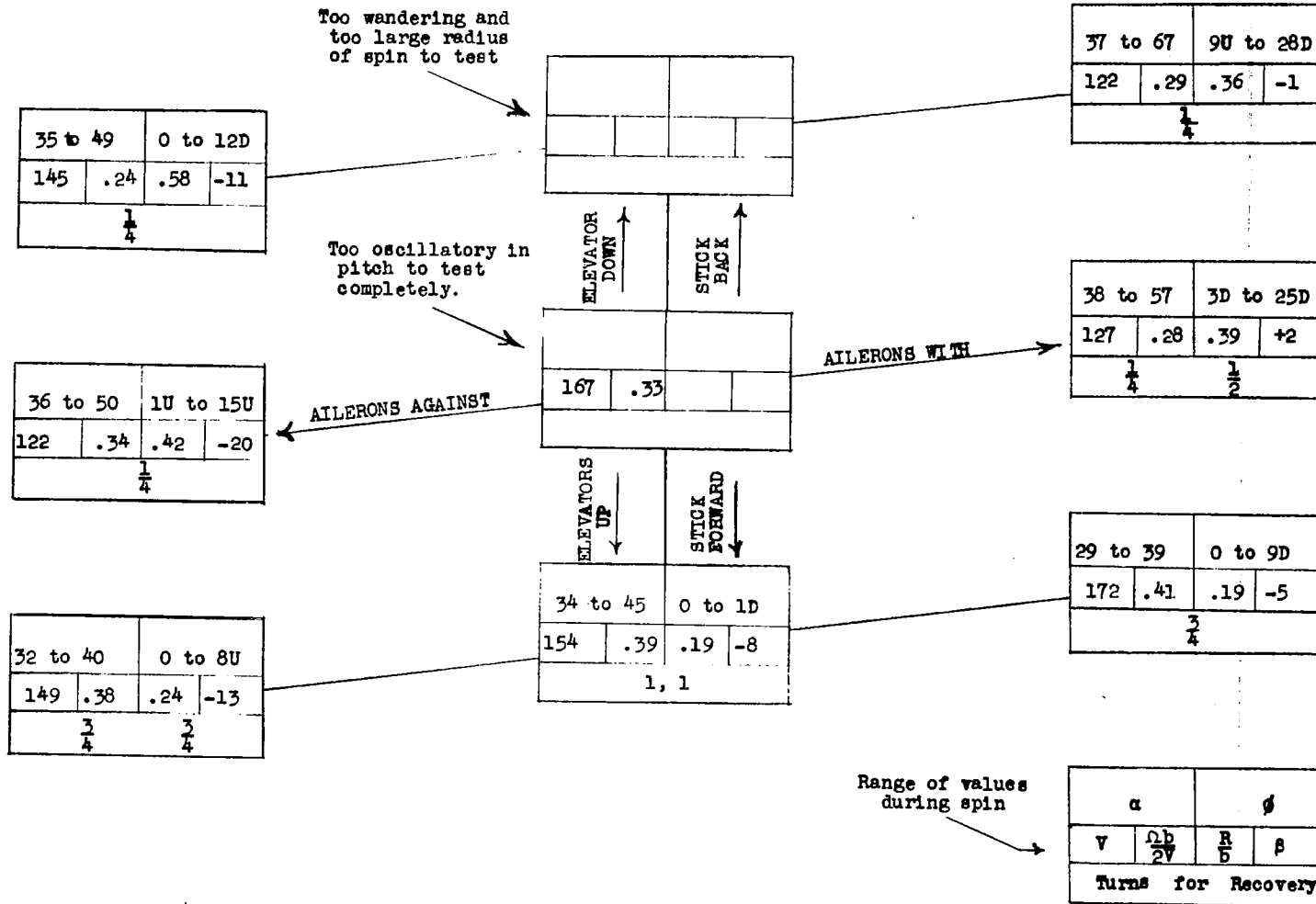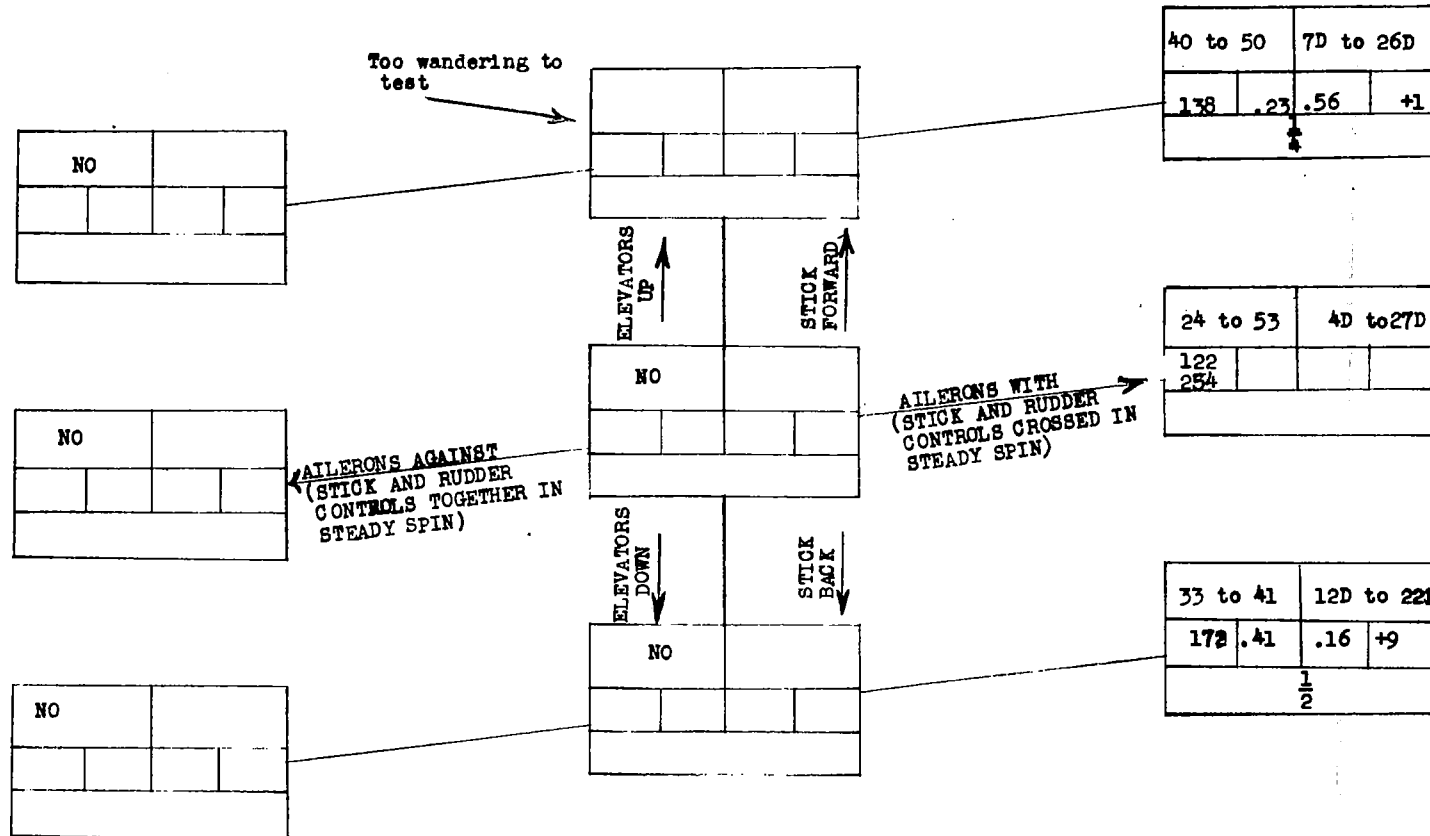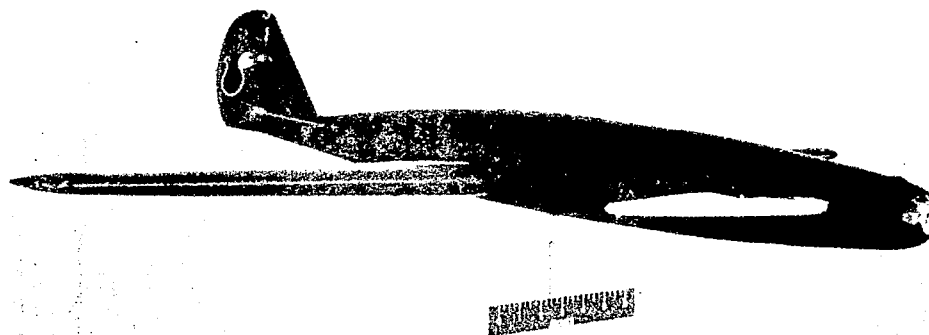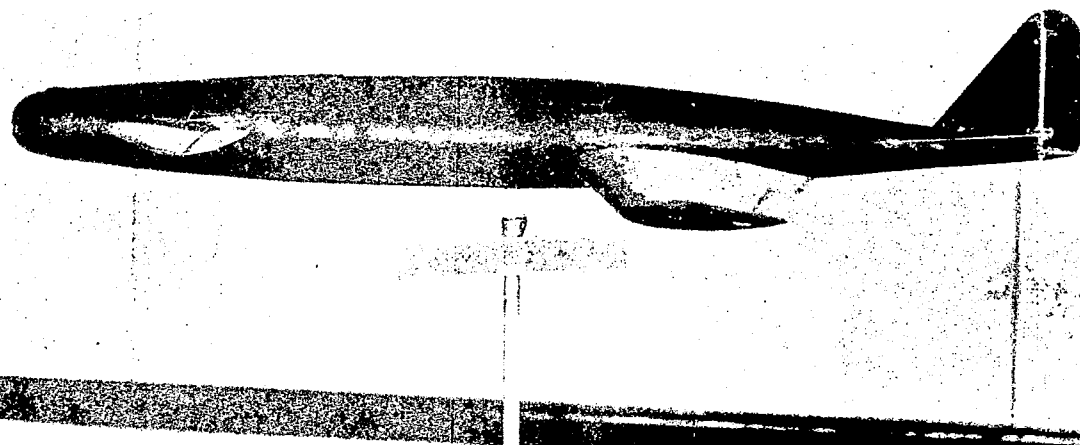

Too wandering to test

NO

NO

NO

ELEVATORS UP

STICK FORWARD

NO

ELEVATORS DOWN

STICK BACK

NO

AILERONS AGAINST (STICK AND RUDDER CONTROLS TOGETHER IN STEADY SPIN)

AILERONS WITH (STICK AND RUDDER CONTROLS CROSSED IN STEADY SPIN)

40 to 50		7D to 26D	
138	.23	.56	+1
		1	

24 to 53		4D to 27D	
122 254			

33 to 41		12D to 22D	
172	.41	.16	+9
		$\frac{1}{2}$	

NO means model would not spin.

α		ϕ	
V	$\frac{\Omega b}{2V}$	$\frac{R}{b}$	β
Turns for recovery			

Chart 2

(a) Three-quarter front view

(b) Side view

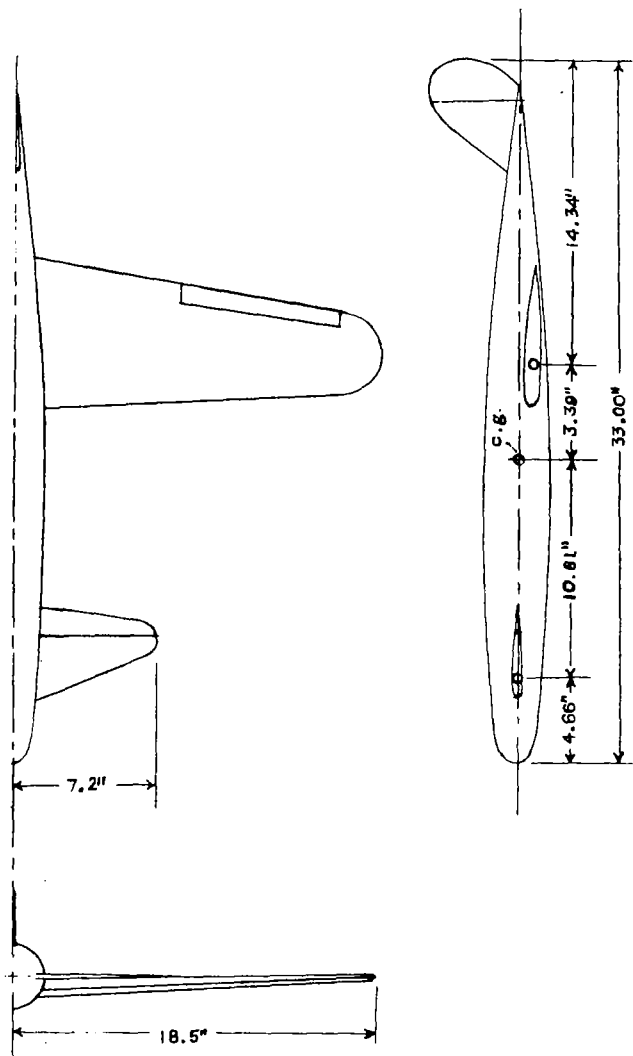Figure 1.- Model of hypothetical canard airplane. 1/24 scale.

Fig. 1

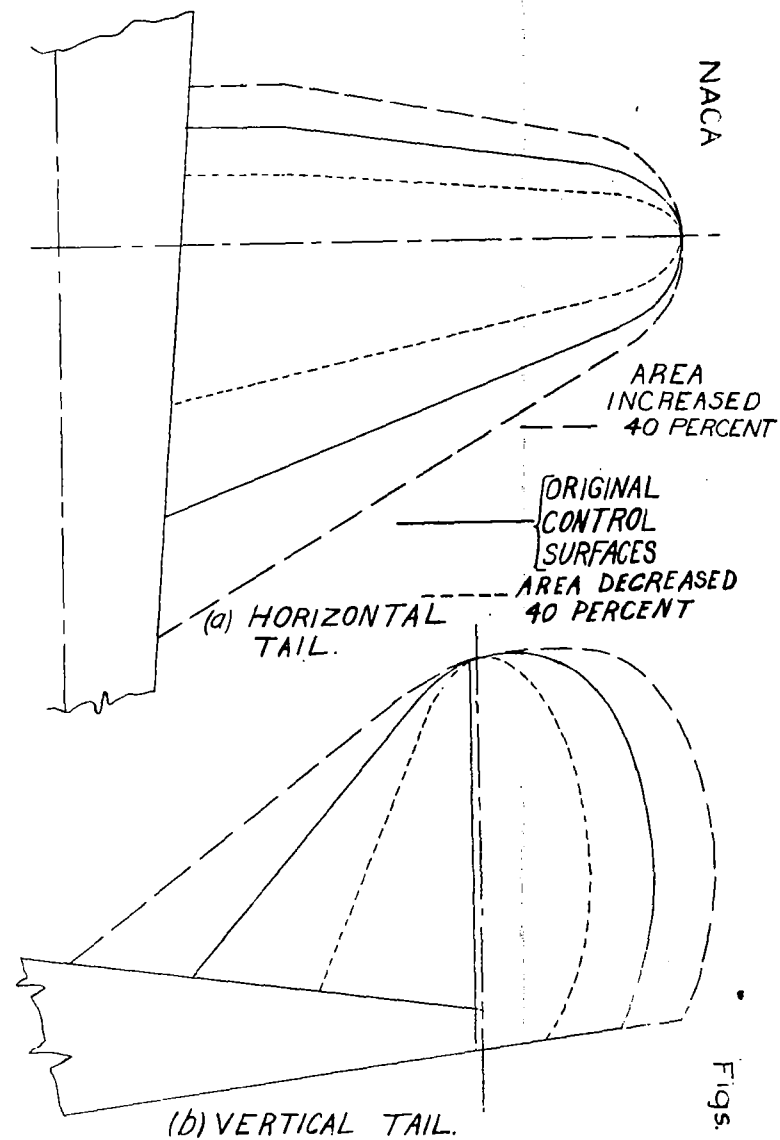Figure 2. – Three views of model of hypothetical canard airplane, $\frac{1}{24}$ scale.

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(a) HORIZONTAL TAIL.

AREA INCREASED 40 PERCENT

ORIGINAL CONTROL SURFACES

AREA DECREASED 40 PERCENT

(b) VERTICAL TAIL.

Figs. 2,3

Figure 3. – Original and modified tail surfaces tested on $\frac{1}{24}$ scale model of canard airplane.